MICRO SYSTEMS, INC.
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NAVAIR

Frequency Agile System

System for Naval Target Control

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The Frequency Agile System

- The Frequency Agile System Provides A New Concept for Naval Target Control:
  - Senses RF Interference ***or*** Multipathing and Automatically Changes Frequencies To Avoid It
  - Provides Multiple High-Speed RF Networks For Complex Target Operations
  - Compatible With Existing Ground Systems, Such As the System for Naval Target Control (SNTC)

Components Of The Frequency Agile System (FAS)

Omni-Directional Antenna

FAS Ground RF Unit*

To Ground Control System

RF Data Link

19 Channels
421.5 MHz to 448.5 MHz

FAS Transponders

FAS Airborne Relay*

FAS Test Set*

*Photographs Provide Conceptual Illustrations Of Anticipated FAS Equipment

FAS Facts

1. FAS Provides 200 NM Line Of Sight Distance with 12 dB of Margin
   - 330 NM Over The Horizon With One Relay Hop (Standard)
   - 730 NM Over The Horizon With Two Relay Hops (Optional)
   - Relay Track Information Is Provided By The Data Link

2. 46 16-Bit Words Are Provided In Each Uplink/Downlink Message
   - Includes Time, Space, Position Information (TSPI)
   - 9 Times More Data Than The Current SNTC, Similar To GRDCS

3. Selectable Uplink/Downlink Rates
   - Each Participant Can Have Its Own Uplink/Downlink Rate
   - Selectable From 1 Hz, 5 Hz, 10 Hz or 15 Hz
   - Uplink/Downlink Rates Remain Fixed During The Mission

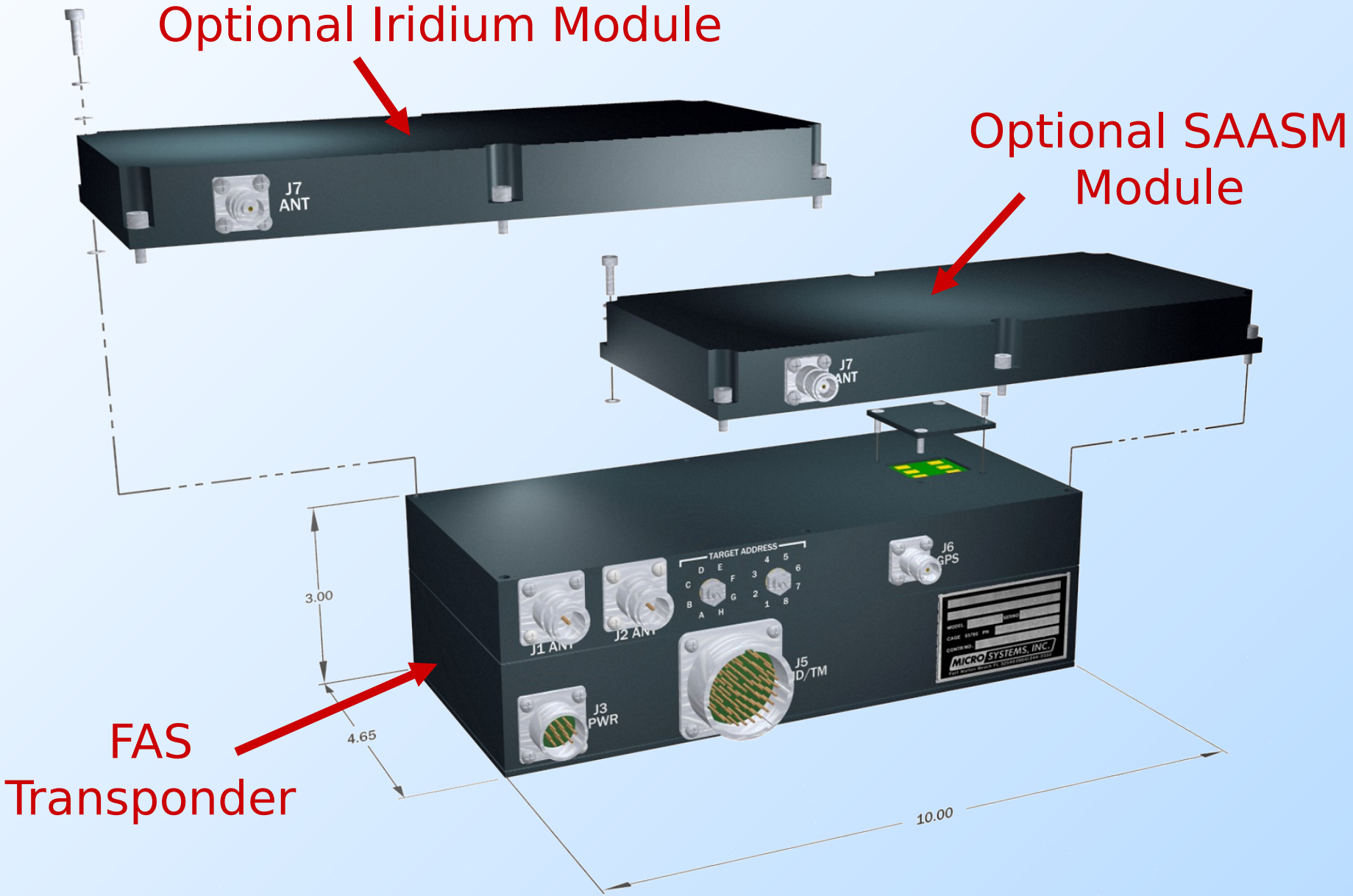
More FAS Facts

4. Can Operate With 1 to 4 RF Networks Simultaneously
   - Example: One RF Network Could Be Used for Subscale Operations, One for Full Scale Operations, and One for Maintenance Operations

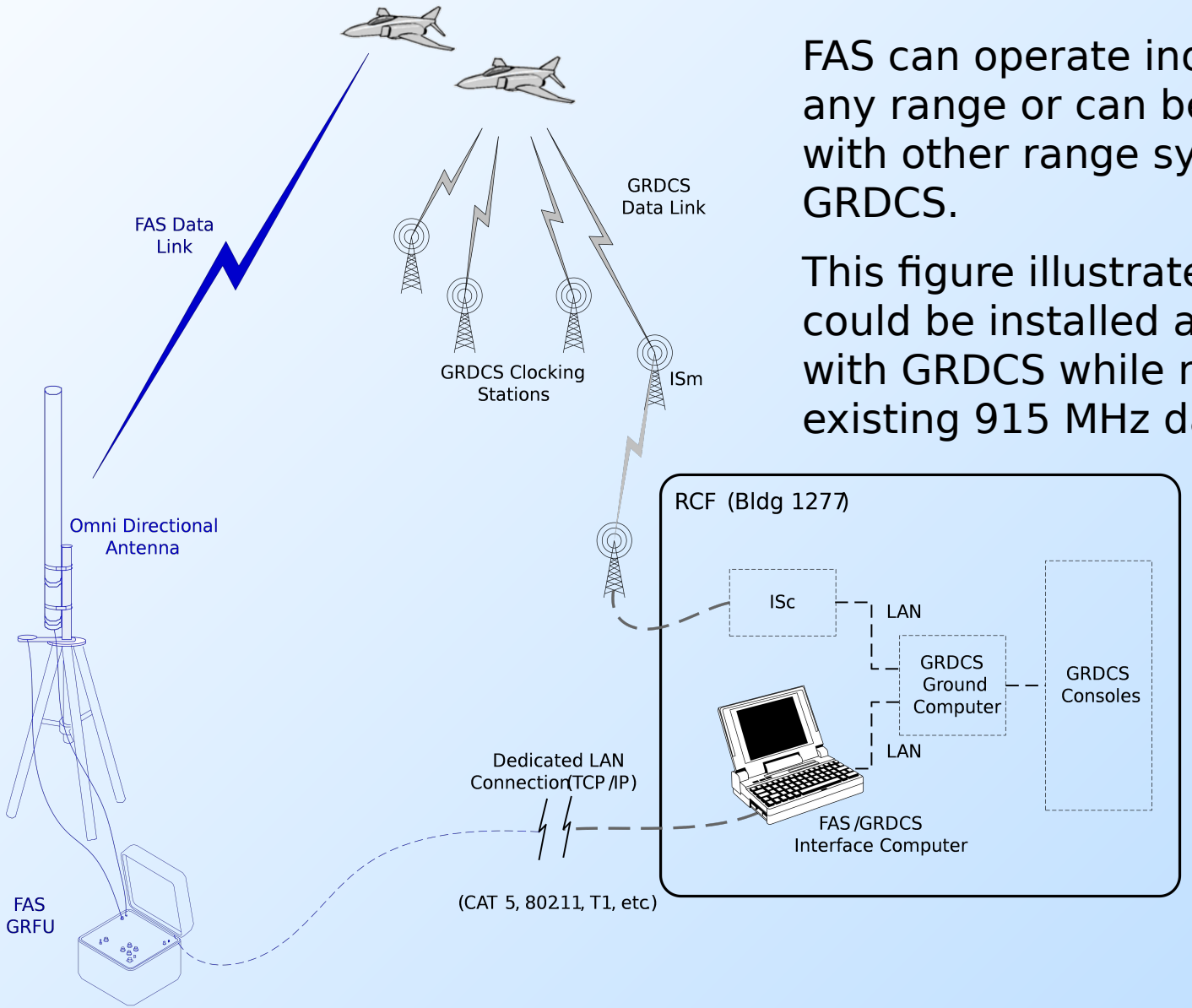
5. A Migration Path Is Provided To Satellite Command & Control
   - Iridium Satellite Module Is A Pre-Planned Product Improvement (P^3I)
   - Electrical & Mechanical Interfaces Provided On All FAS Transponders

6. Can Operate In GPS-Denied Environments
   - Selective Availability Anti-Spoofing Module (SAASM) Is A P^3I
   - Electrical & Mechanical Interfaces Provided On All FAS Transponders
   - If L2 Band Is Also Denied, TSPI Can Be Obtained From External INS

FAS Transponder System



The Frequency Agile System Is Portable



FAS can operate independently of any range or can be integrated with other range systems, such as GRDCS.

This figure illustrates how the FAS could be installed and operated with GRDCS while maintaining the existing 915 MHz data link.

Goals Of The Frequency Agile System

The Frequency Agile System Was Conceived During A Study Commissioned By Navy PMA-208 To Address The Following Goals For The System for Naval Target Control:

1. ***Improved Resistance To Interference***
2. ***Increased Data Link Reliability***
3. ***Higher Data Throughput For All Targets***
4. ***Support for Complex Mission Scenarios***
5. ***Low Implementation Risk***
6. ***Low Implementation Cost***

GOAL 1: *Improved Resistance To Interference*

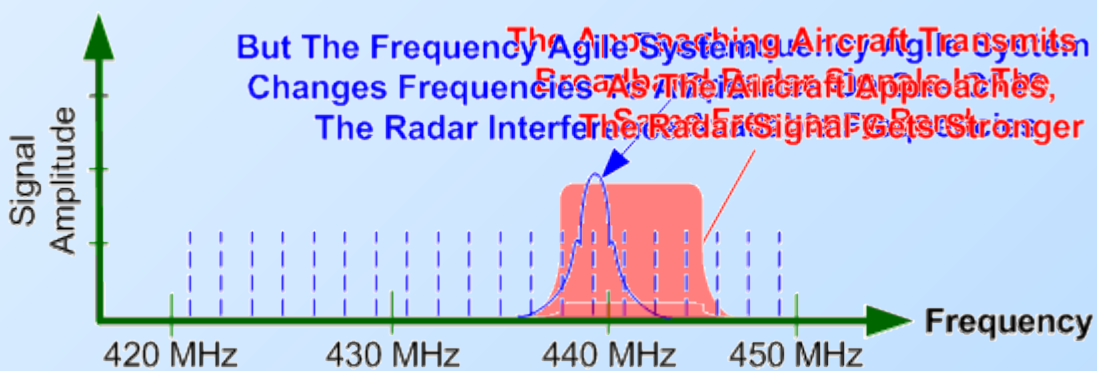
- SNTC's 435 MHz to 450 MHz Band Is Shared
  - E-2C Surveillance Radars, Amateur Radio Operators, Flight Termination Systems and EPLRS/SADL
- Each Of These Systems Can Interfere With SNTC
  - Effective Command/Telemetry Rate Can Be Affected
    - Can Even Stop In The Presence Of Strong Interference
  - Can Lead To Aborted Missions
- SNTC Frequency Cannot Be Changed After Launch
  - If Interference Starts, There's Nothing The SNTC Operator Can Do
  - One Workaround: Operate On Known "Quiet" Channels Only
    - But This Limits System Capabilities

Example Of Interference From E-2C

An E-2C Approaches

New Tx/Rx Frequency: 429.5 MHz

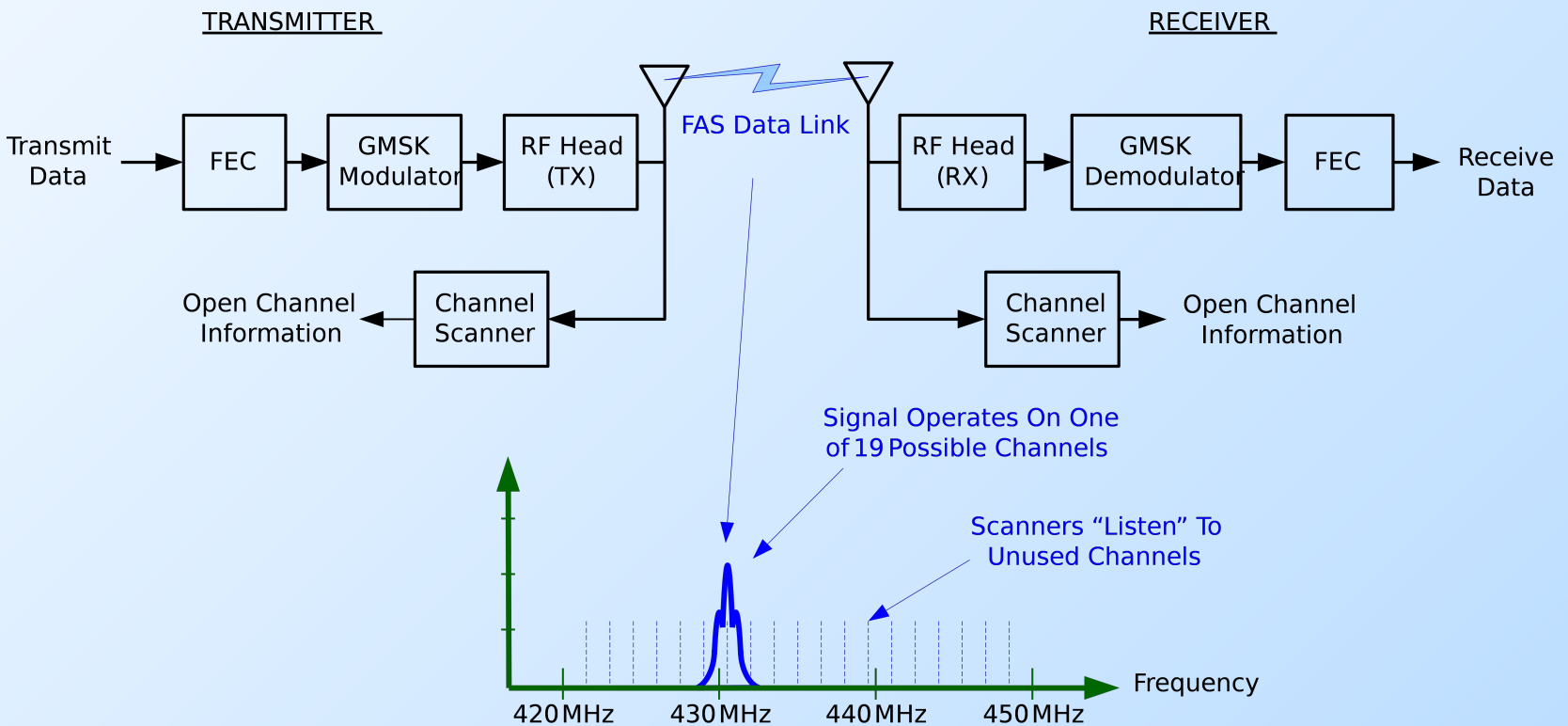
Frequency Agile System Ground RF Unit and Antenna


But The Frequency Agile System Changes Frequencies As The Aircraft Approaches, The Radar Interference Gets Stronger
The Approaching Aircraft Transmits Broadband Radar Signals In The Same Frequency Range
Signal Amplitude
420 MHz
430 MHz
440 MHz
450 MHz
Frequency

FAS Frequency Scanners

Each FAS Radio Has It's Own Frequency Scanner

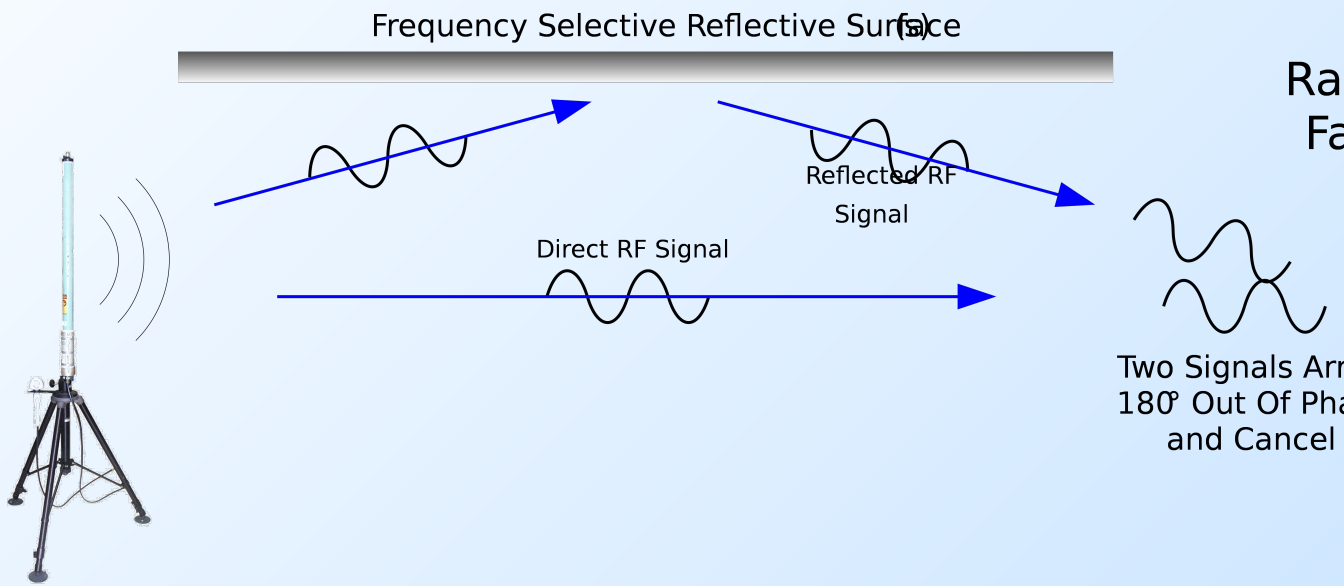
- Each Scanner "Listens" To Each Unused Channel
- Quiet Channels Are Marked As Available
- The Ground System Collects Channel Data From All Transponders and Determines The Best Alternate Frequencies

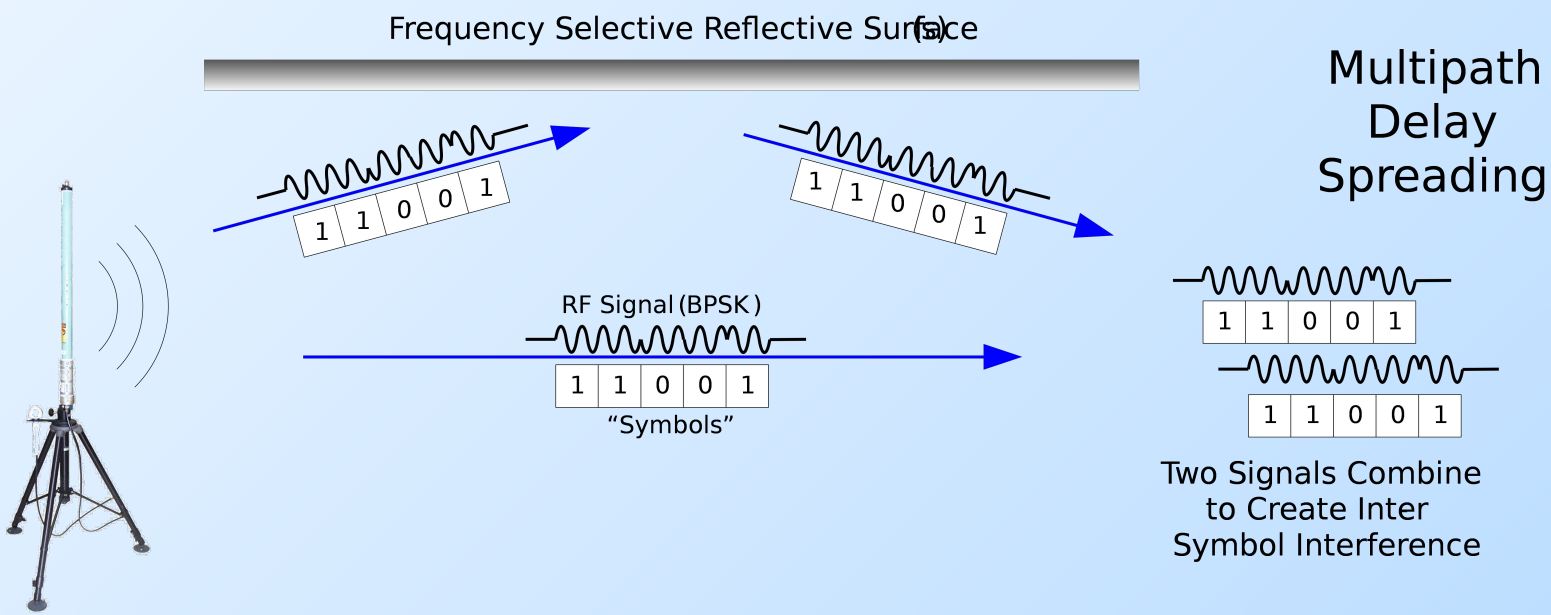


The Concept Of Frequency Agility

- The Frequency Agile System Is *Not* A Frequency Hopper
  - It Operates On A Single Frequency Unless Forced To Switch
  - Will Not Normally Switch Frequencies During Operation
    - Requires Severe Interference, Multipathing, or User Command
- FAS Will Not Switch Into Another Problem Area
  - Only Switches To Pre-Scanned “Quiet” Frequencies
- Won’t Switch To An Unapproved Frequency
  - Any Of The FAS Frequencies Can Be Blocked By Local Operators
  - Will Not Create Problems For Other Systems
- Exploits Unused Frequencies As They Become Available
  - Most RF Systems Turn On and Off Throughout The Day
  - FAS Will Detect These Frequencies As They Become Available

Resistance To Multipathing


Frequency Selective Reflective Surface (s)
Reflected RF Signal
Direct RF Signal
Rayleigh Fading
Two Signals Arrive 180° Out Of Phase and Cancel


Frequency Selective Reflective Surface (s)
1 1 0 0 1
1 1 0 0 1
RF Signal (BPSK)
1 1 0 0 1
"Symbols"
Multipath Delay Spreading
1 1 0 0 1
1 1 0 0 1
Two Signals Combine to Create Inter Symbol Interference

How FAS Avoids Multipathing

- The Frequency Agile System Detects Multipathing Two Ways:
  - RF Signal Degradation (Rayleigh Fading)
  - Multiple Data Errors With Strong RF Signal (Delay Spreading)
- If Any Radio Detects Either Condition, The System Will Switch To An Alternate Frequency
  - Multipathing Is Very Sensitive To Frequency
  - Small Frequency Changes (~10 MHz) Are Very Effective

GOAL 2: ***Increased Data Link Reliability***

- SNTC Typically Operates Between 80% and 100% TQUAL
  - 100% TQUAL = No Missed Messages
  - 80% TQUAL = 20 Out Of Every 100 Downlink Messages Are Lost
- Lost Messages Are Highly Undesirable for T&E
  - Command Dropouts Can Cause Jerky Stick Response
  - Telemetry Dropouts Can Result In Over-Driving The Target
  - T&E, Weapons Developers, and Engineering Investigations Require All Possible TM Data For Post Mission Analyses

FAS Is Designed for TQUAL ≥99% With 12 dB Margin

- Any Scenario, Any Target
- Designed For 12 dB Of Margin At Max Distance
  - 200 NM Max Distance With Standard Omni-Directional Antennas
  - 250 NM Max Distance With Semi-Directional Panel Antennas

GOAL 3: ***Higher Data Throughput***

Maximum SNTC Data Throughput (Current System):

- 10 Hz Uplink/Downlink Message Rate
  - Maximum Rate In Direct Line Of Sight Mode
- 48 Data Bits Per Uplink, 120 Data Bits Per Downlink
- Throughput = (48 + 120) * 10 = ***1,680 Data Bits Per Second***

Maximum Data Throughput For SNTC With FAS:

- 15 Hz Uplink/Downlink Message Rate
  - Same In Direct Line of Sight **OR** Relay Mode
- 512 Data Bits In Each Uplink and Downlink Message
- Throughput = (512 + 512) * 15 = ***15,360 Data Bits Per Second***

SNTC With FAS Can Provide Full Scale Target Control

GOAL 4: ***Support For Complex Mission Scenarios***

Maximum Capabilities For SNTC With FAS:

- 8 Targets Per Frequency At 10 Hz Rate Within Line Of Sight
- 4 Targets Per Frequency At 10 Hz Rate With Airborne Relay
- 40 Surface Targets Per Frequency At 1 Hz Rate, Relay or LOS
- Maximum of 4 Frequency Groups Per System

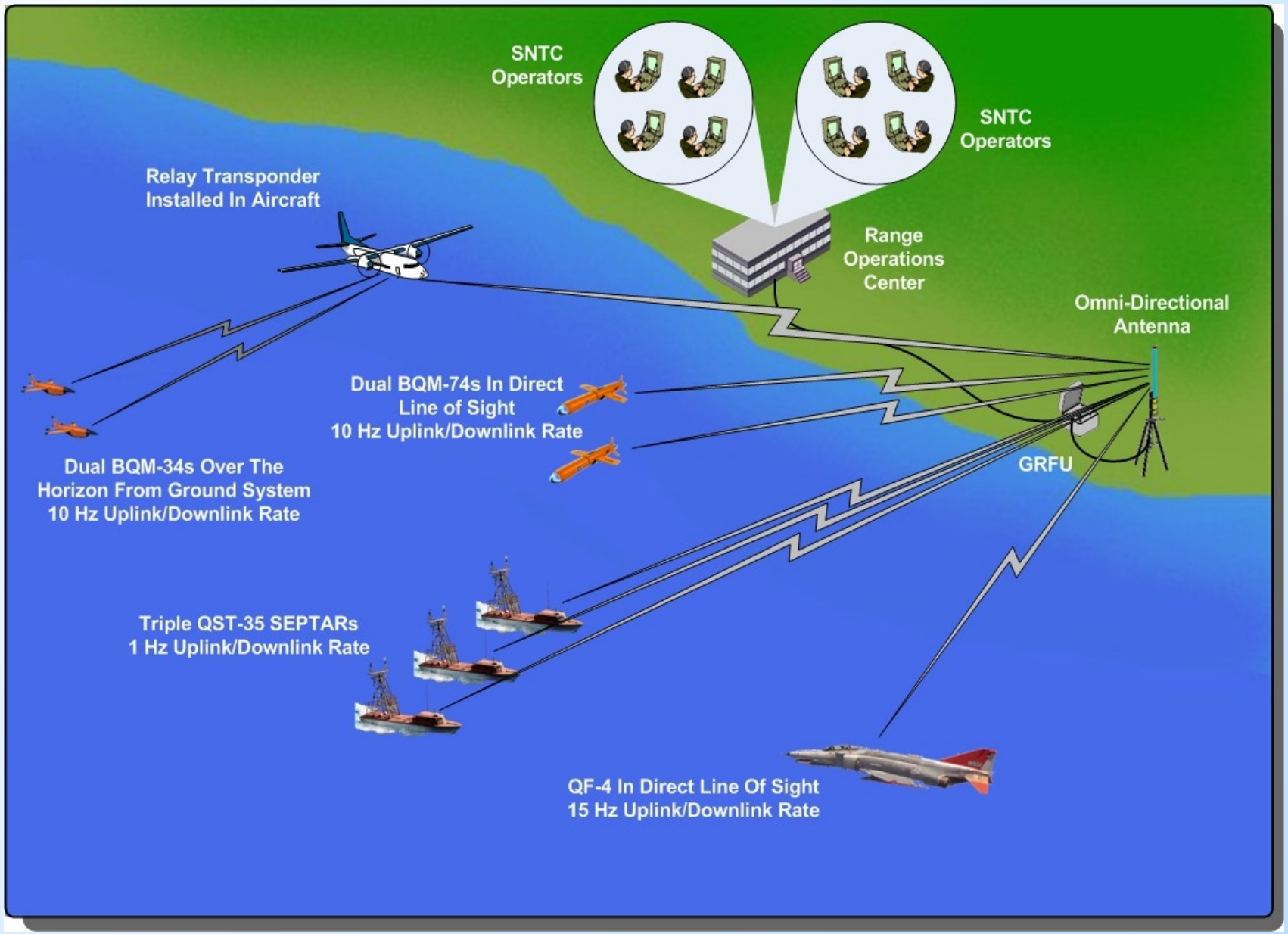
Therefore, SNTC With FAS Can Control Up To:

- ***32 Subscales or Full Scales In Line Of Sight At 10 Hz***
- ***Or Up To 16 Subscales or Full Scales Through A Relay***
- ***Or Up To 160 Surface Targets Through A Relay at 1 Hz***

FAS Also Allows Mixed Modes of Target Types, Relays, and Uplink/Downlink Rates

- Thousands of Scenarios Possible

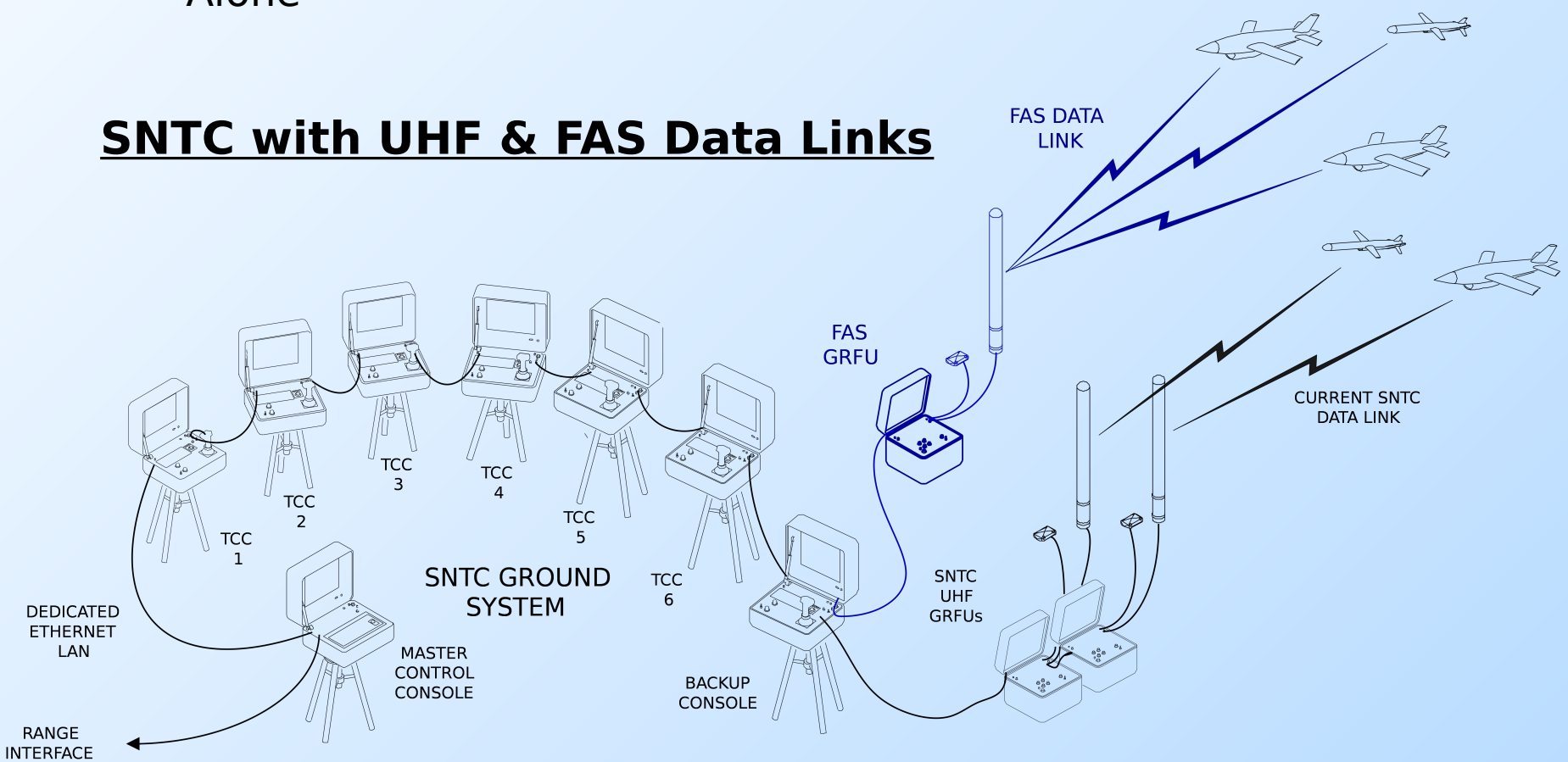
Example Scenario With One RF Network



GOAL 5: *Low Implementation Risk*

- FAS Exploits SNTC's "Plug 'n Play" System Architecture
  - Plugs Directly Into The SNTC LAN
  - Installing FAS On Existing SNTC Systems Will Not Cause Down-Time
  - Can Be Used In Combination With Existing UHF Data Link Or Stand-Alone

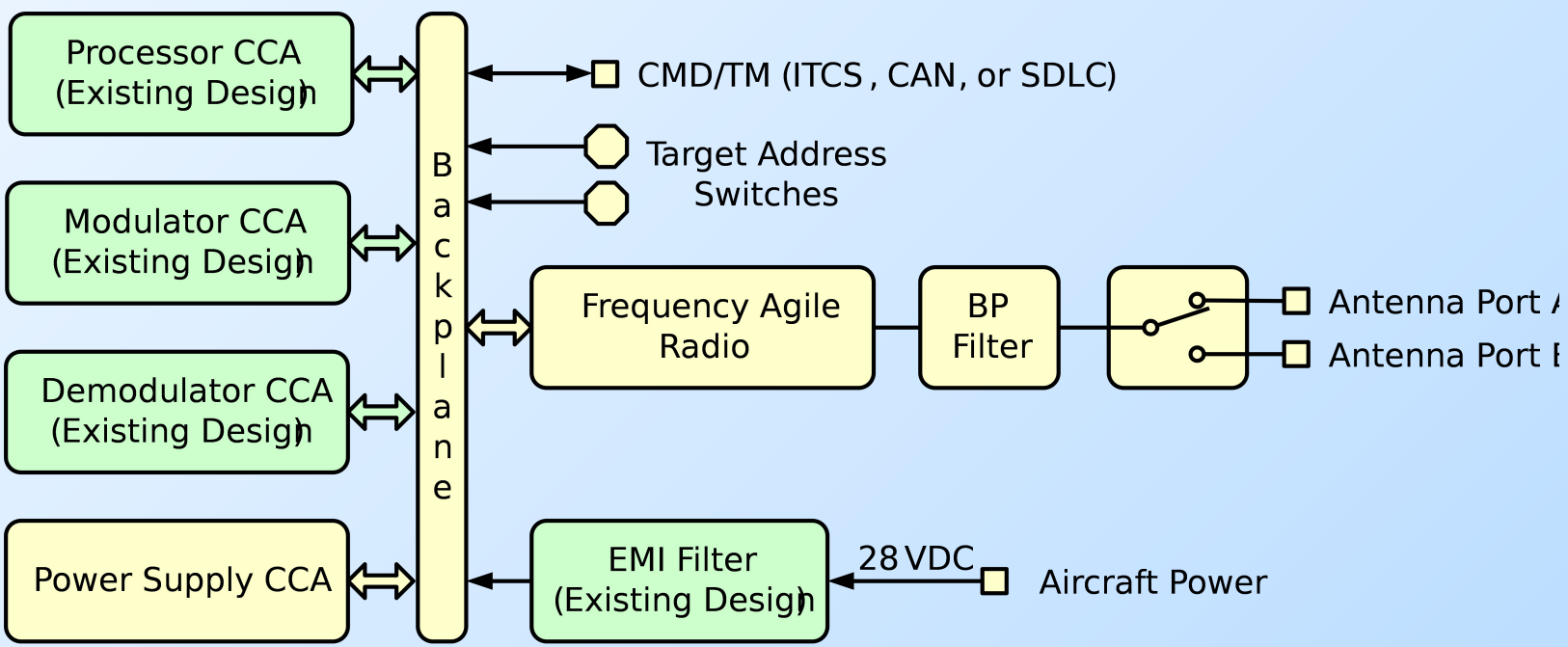
SNTC with UHF & FAS Data Links



Reuse of Existing Designs

- Major Radio Subassemblies Have Been Previously Developed On The Navy's Early Success Data Link (ESDL) MSTCS Program
  - Same Radio Is Used On FAS Transponder, GRFU, Relay & Test Set
  - All ESDL Subassemblies Have Already Been Qualified for Temperature, EMI, Vibration, Shock, Altitude, etc.

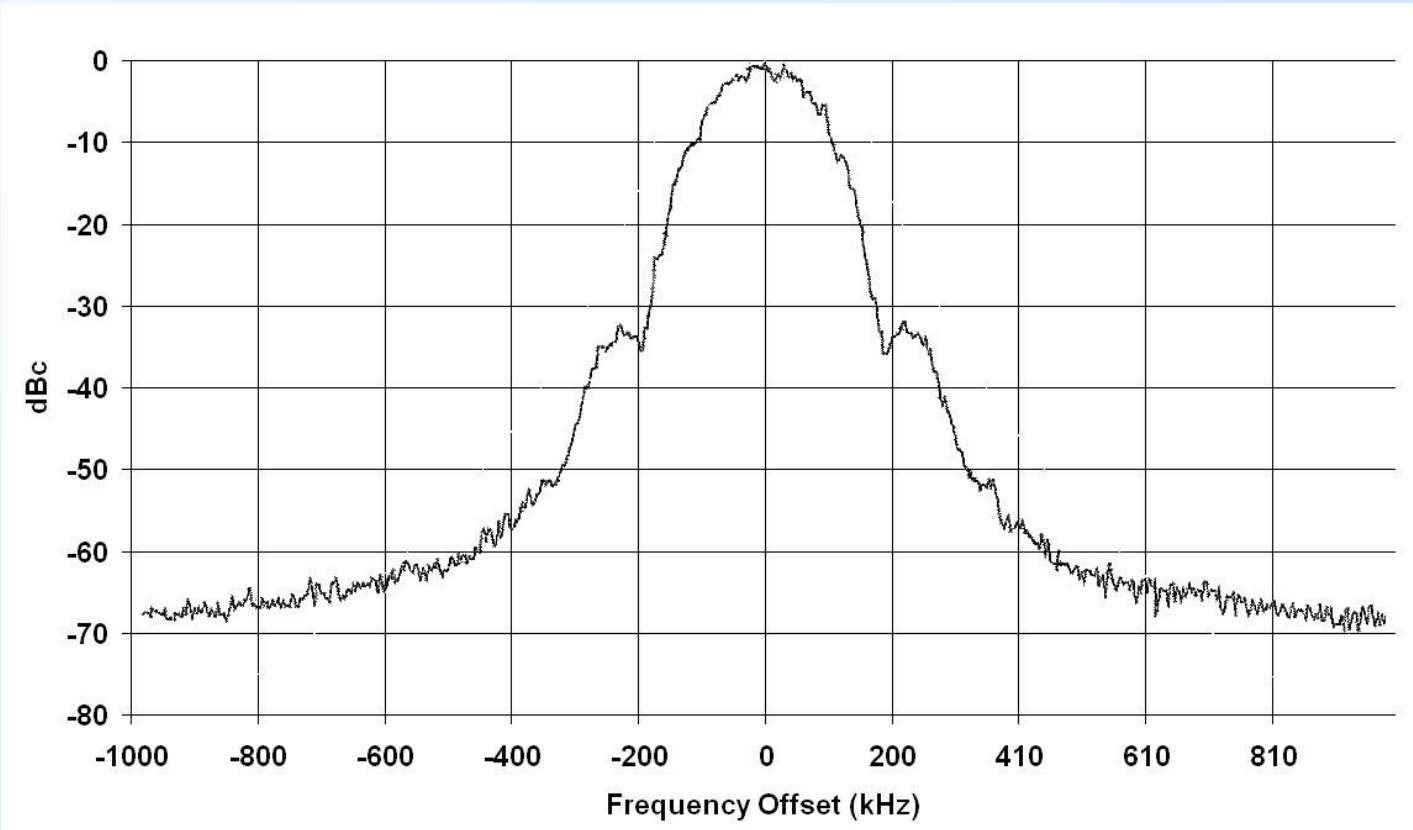
FAS Transponder Block Diagram



Established Modulation Technique

Like ESDL, FAS Uses Gaussian Minimum Shift Keying (GMSK)

- Very Efficient Spectrum Usage -- Similar To SOQPSK
- FAS Transmit Spectrum Shown With 265 kbps Burst Data Rate



Other Technical Details

Forward Error Correction (FEC)

- Detects and Corrects Errors In The Uplink and Downlink Data
- IEEE 802.16a Turbo Product Codes Used For Best Efficiency

24-Bit Cyclic Redundancy Check (CRC)

- Prevents Any Possibility of Erroneous Commands or Telemetry
- Standard TCP/IP (Ethernet) Polynomial

Multiple Transponder Interfaces

- ITCS (Legacy), CDA (CANBus), and SDLC (Synchronous RS-422)

Low Power Consumption

- 38 Watts, Average Transponder Power

Frequency Allocation

- DD Form 1494, Request for Authorization, Submitted December, 2004
- Note G8 Of The NTIA Redbook, January 2005 States:

  "Low Power Government Radio Control Operations Are Permitted In The Band 420 – 450 MHz"

- The Navy Marine Corps Spectrum Center (NMSC) Stated Earlier:

  "We see no reason that this proposed modification [to SNTC] should not be approved. Particularly since it will help avoid interference situations"

- NMSC Has Indicated That The Frequency Authorization (J/F 12) Will Most Likely Be Approved In Early 2006

GOAL 6: ***Low Implementation Cost***

- No New Transponder Mounting Requirements For Existing Targets
- Reduced Ground Equipment Requirements
  - Fewer FAS GRFUs Are Needed For The Same Mission Requirements
  - FAS Uses Same Antennas and RF Cabling As SNTC
  - No New Ground or Target Antenna Installations Are Required
- No Hardware Changes Required To SNTC Consoles
  - All FAS Ground System Functions Are Implemented In Software
  - Navy Does Not Lose Its Original Investment In SNTC Equipment
- Target Design To Production Cost:
  - Same As or Less Than Current SNTC Transponder
  - Same As or Less Than Current SNTC GRFU

Summary

Parameter	Current SNTC	SNTC With FAS
Frequency Band	435 – 450 MHz	420 – 450 MHz
Resistance To Interference	No Built-In Resistance	Excellent
Resistance To Multipathing	No Built-In Resistance	Excellent
Uplink/Downlink Message Rate	4 Hz to 10 Hz, depending on mission configuration	1 Hz, 5 Hz, 10 Hz, or 15 Hz, user defined
Data Link Reliability	80% to 100%, typical	99% to 100%, typical
Data Throughput	1,680 data bits per second	15,360 data bits per second
Maximum Number Of Subscale Targets	8 in LOS Mode @ 7 Hz 8 in Relay Mode @ 4 Hz	32 in LOS Mode @ 10 Hz 16 in Relay Mode @ 10 Hz
Maximum Number Of Full Scale Targets	Not Supported	32 in LOS Mode @ 10 Hz 16 in Relay Mode @ 10 Hz
Maximum Number Of Surface Targets	32 at 1 Hz, any mode	256 in LOS Mode @ 1 Hz 160 in Relay Mode @ 1 Hz
Target Interface	ITCS Bus Only	ITCS, CAN, or RS-422 Bus
Automatic Data Error Correction	None	Turbo Product Code FEC
Data Integrity Checking	8-Bit Checksum	24-Bit Cyclic Redundancy Check